

US008665499B2

(12) **United States Patent**
Malik et al.

(10) **Patent No.:** **US 8,665,499 B2**
(45) **Date of Patent:** **Mar. 4, 2014**

(54) **ISOLATED HOLE DETECTION AND GROWTH**

(75) Inventors: **Amal Malik**, Pittsford, NY (US);
Zhenhuan Wen, Pittsford, NY (US);
Xing Li, Webster, NY (US)

(73) Assignee: **Xerox Corporation**, Norwalk, CT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 57 days.

(21) Appl. No.: **13/547,839**

(22) Filed: **Jul. 12, 2012**

(65) **Prior Publication Data**

US 2014/0016157 A1 Jan. 16, 2014

(51) **Int. Cl.**
H04N 1/407 (2006.01)

(52) **U.S. Cl.**
USPC **358/3.26**; 358/3.04; 358/3.06; 382/163;
382/275

(58) **Field of Classification Search**
USPC 358/3.26, 3.04; 382/163, 275
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,634,088 A 5/1997 Banton
5,659,399 A 8/1997 Lin et al.

5,859,955 A 1/1999 Wang
6,332,044 B1 12/2001 Loce et al.
6,389,163 B1 5/2002 Jodoin et al.
7,406,210 B2 7/2008 Handley et al.
2006/0197992 A1 9/2006 Wang
2007/0091369 A1* 4/2007 Liu et al. 358/1.18
2007/0201097 A1 8/2007 Anderson et al.
2008/0310748 A1 12/2008 Arai et al.
2012/0162719 A1* 6/2012 Klaus 358/3.13

* cited by examiner

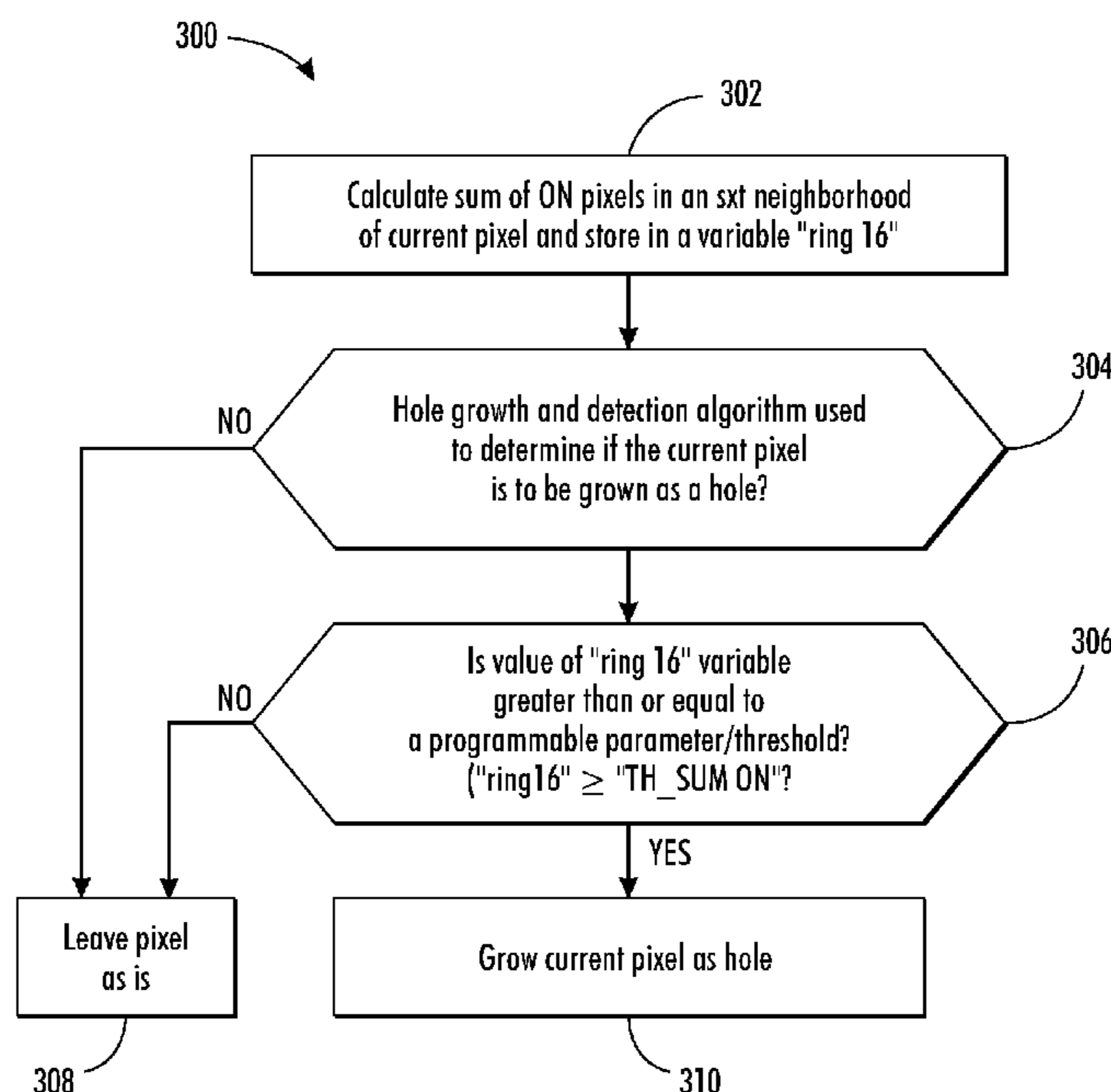
Primary Examiner — Qian Yang

(74) *Attorney, Agent, or Firm* — Pillsbury Winthrop Shaw Pittman, LLP

(57) **ABSTRACT**

The present disclosure relates to a method and system for processing isolated holes in an image to be printed or displayed. The method includes detecting whether pixels corresponding to an isolated hole in the image are in an off state, determining a sum of pixels that are in an on state in a first pixel ring surrounding the pixels corresponding to the isolated hole when the one or more pixels in the isolated hole are detected to be in the off state, comparing the sum of pixels in the pixel ring that are in the on state with a threshold sum, turning off a number of pixels in at least another pixel ring either comprising of or surrounding the pixels when the first sum of pixels in the on state is greater than the threshold sum, and outputting the isolated hole including the turned off first number of pixels.

18 Claims, 9 Drawing Sheets



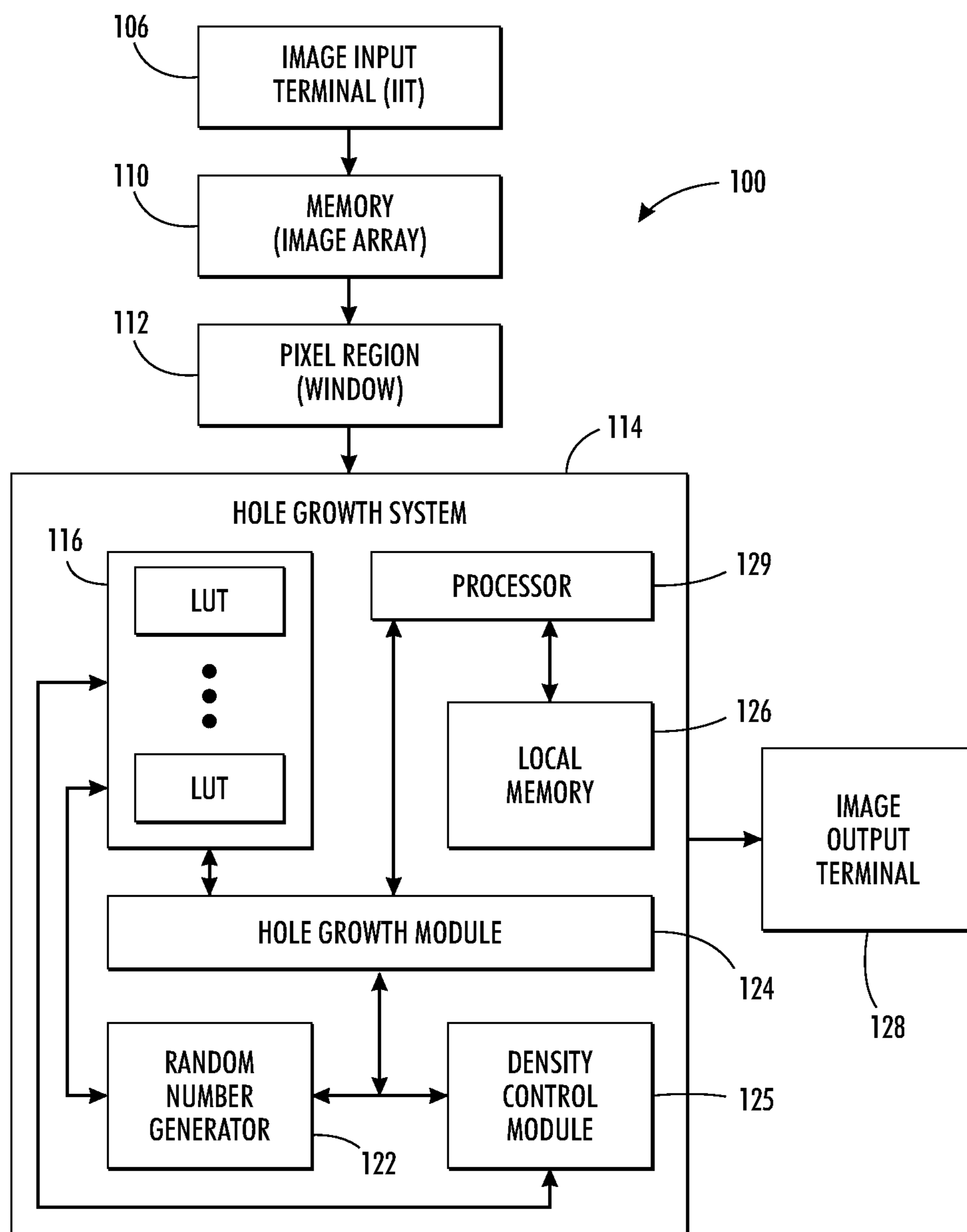


FIG. 1

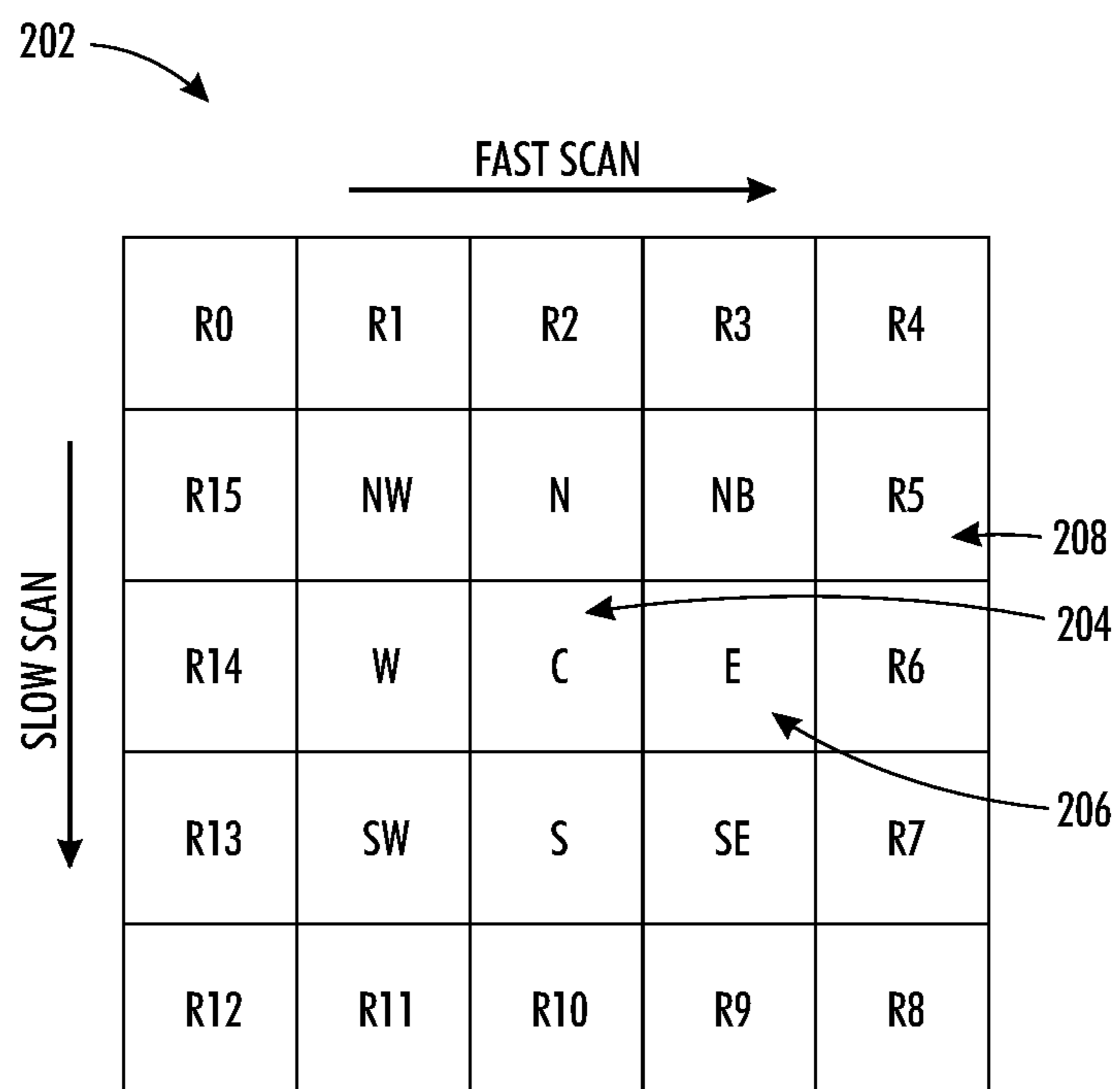


FIG. 2A

PATTERN SET FOR HOLE GROWTH FACTOR = 4

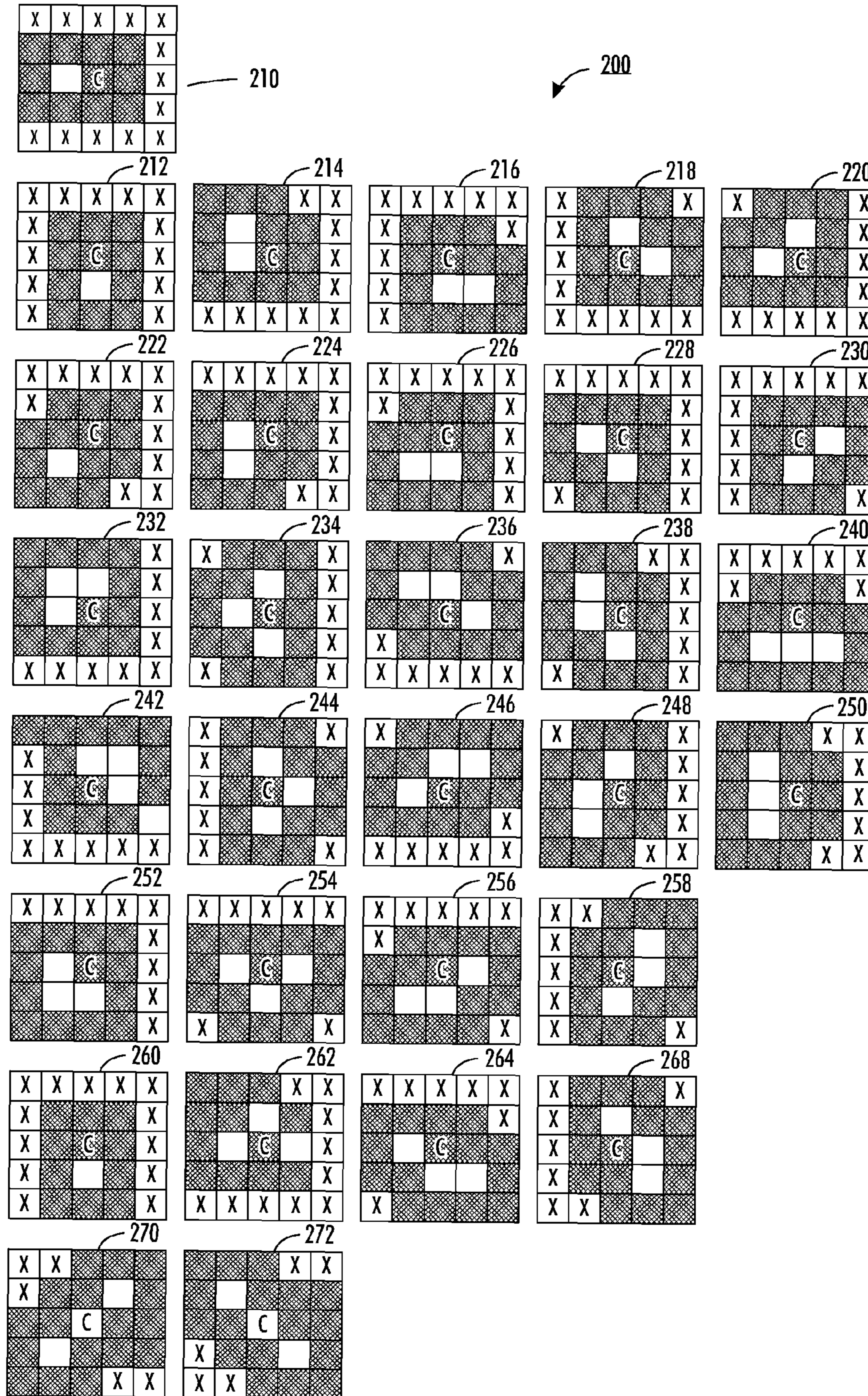


FIG. 2B

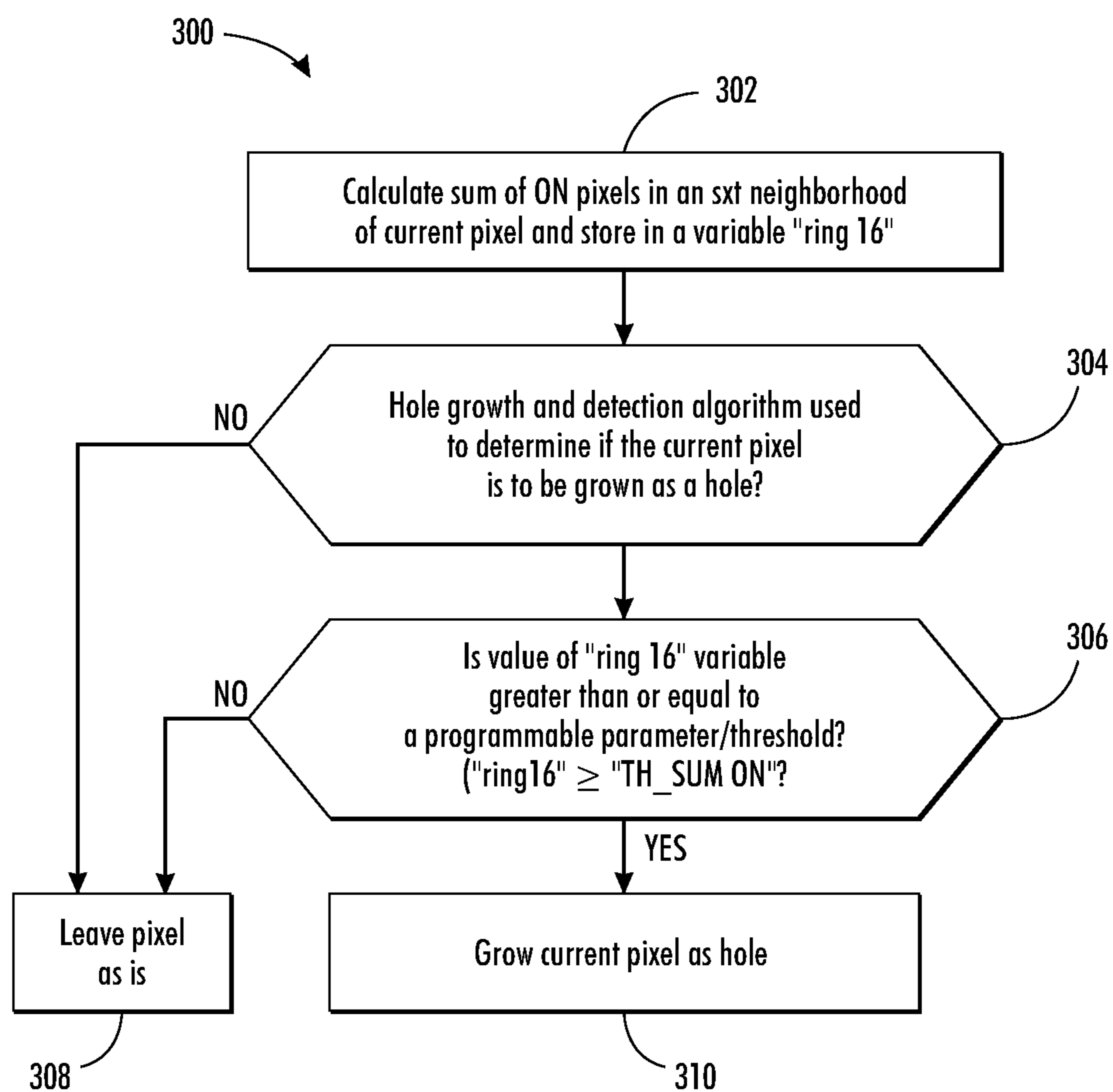


FIG. 3

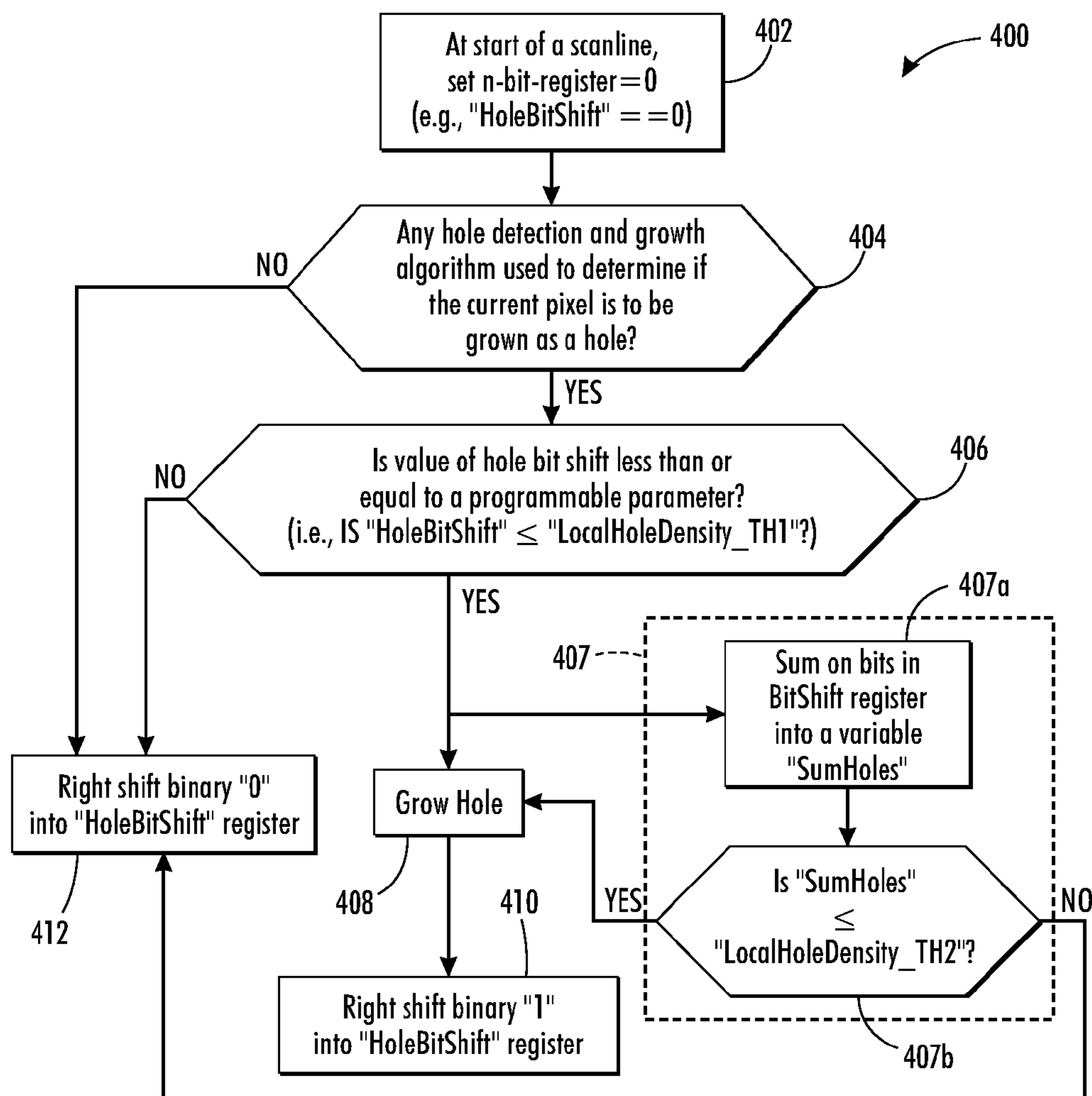


FIG. 4

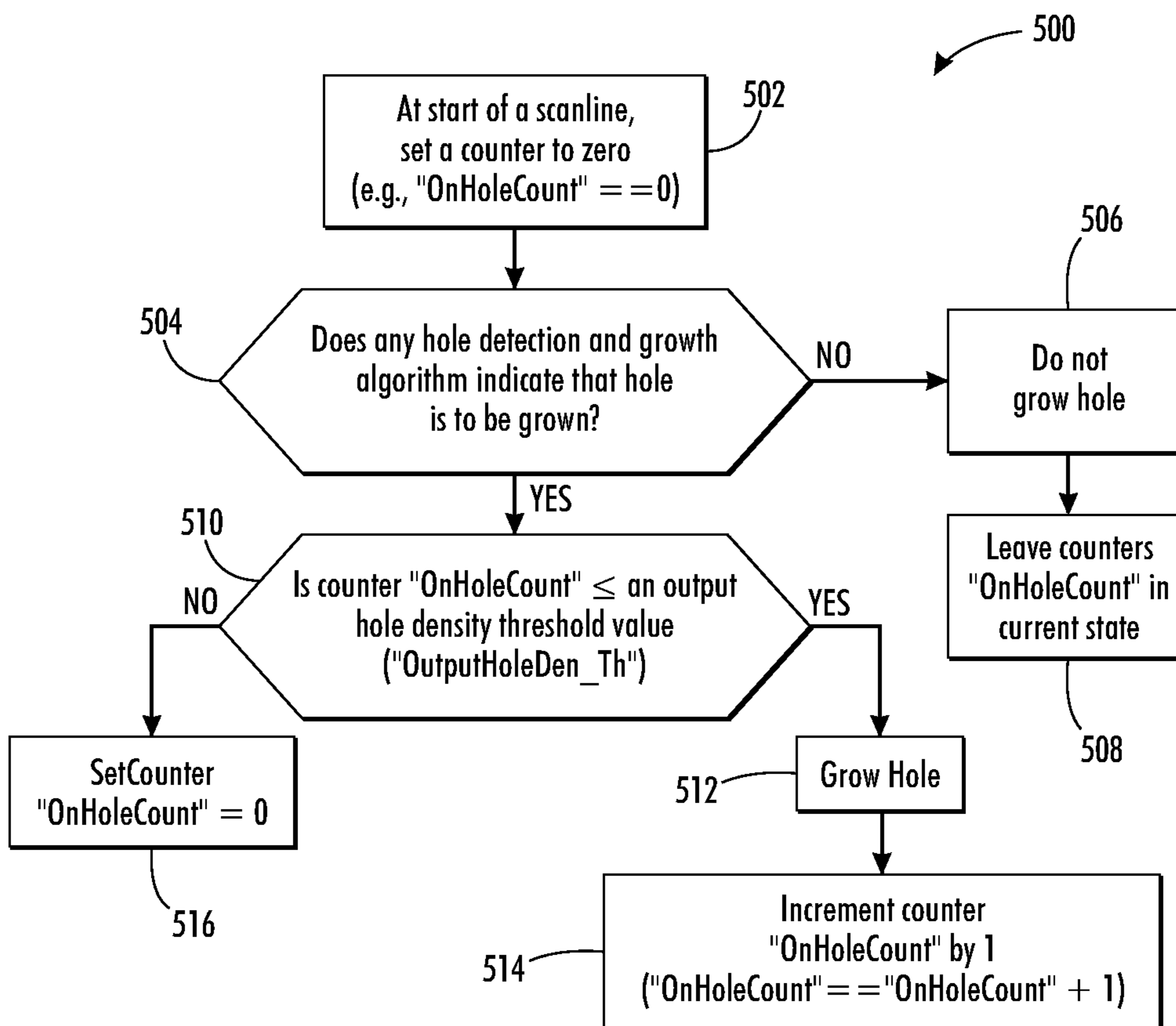


FIG. 5

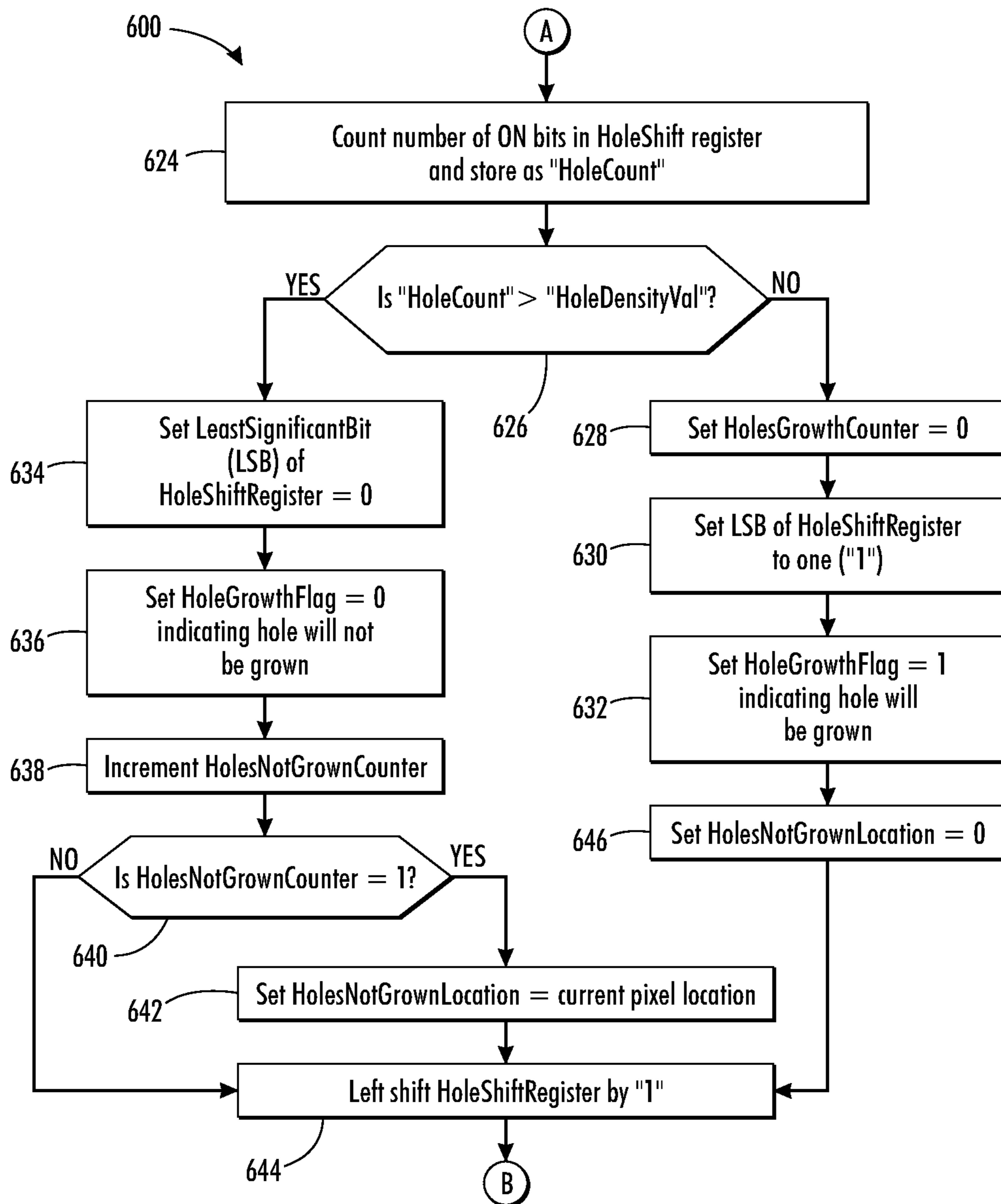


FIG. 6

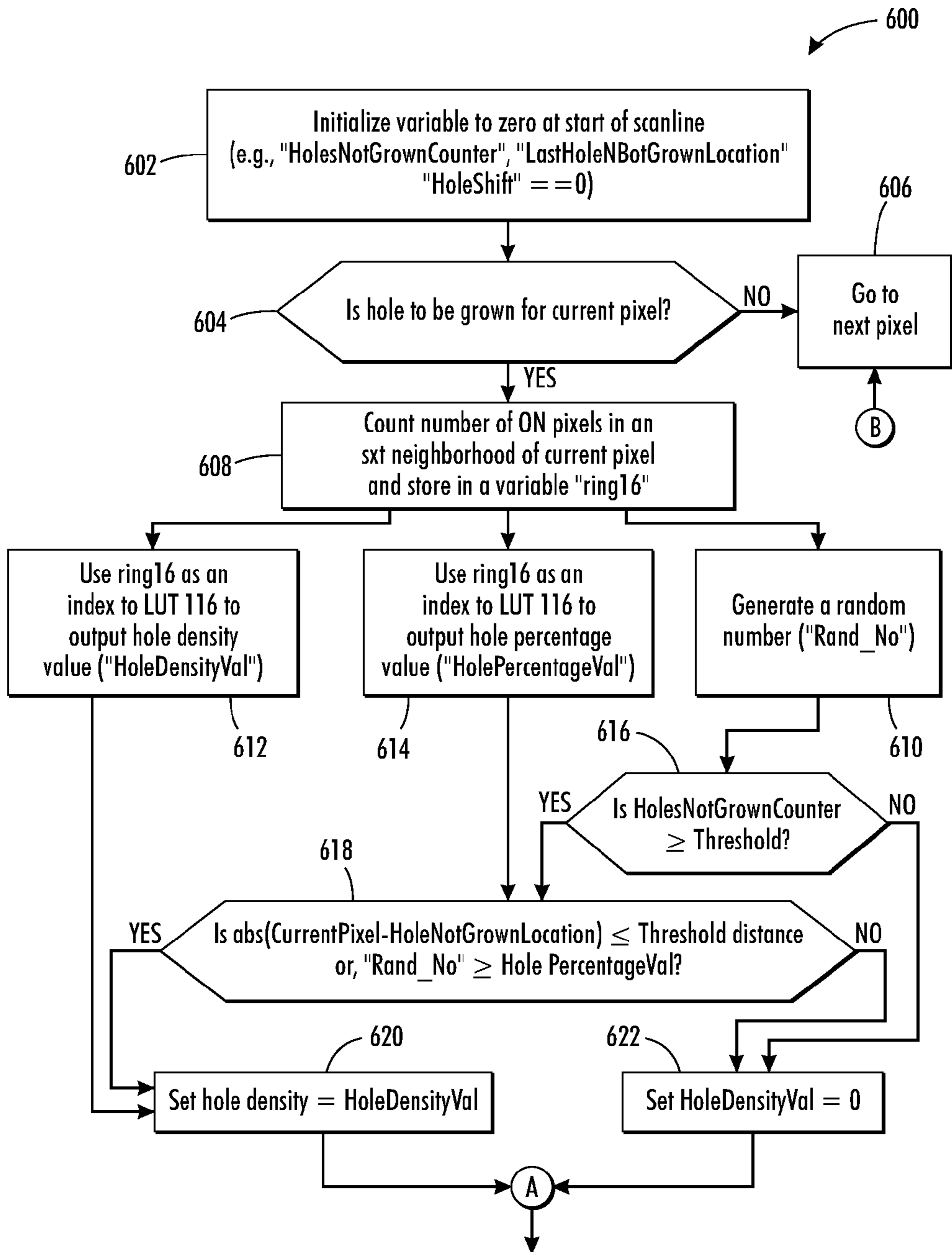


FIG. 6(Contd.)

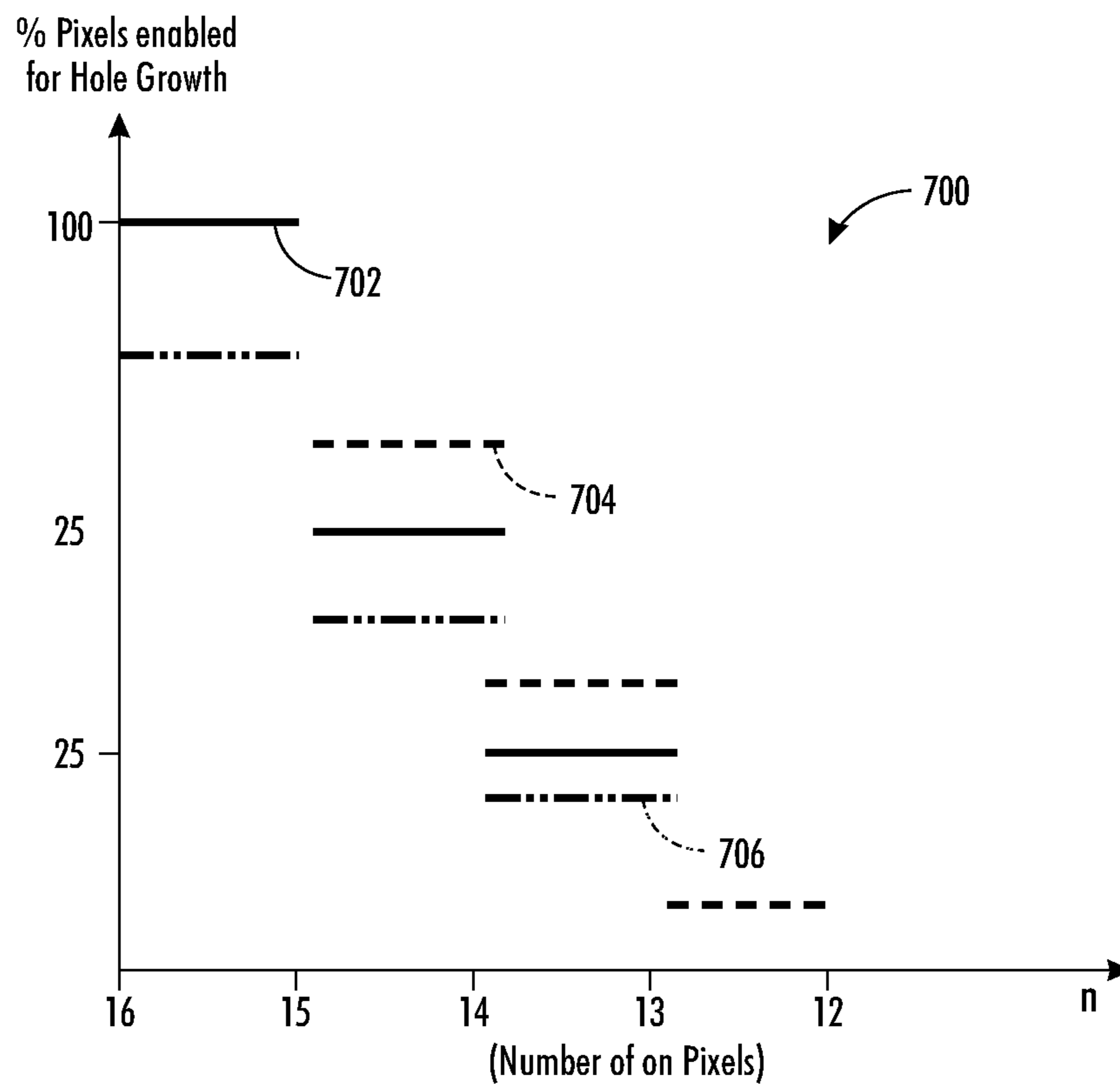


FIG. 7

1

ISOLATED HOLE DETECTION AND GROWTH

CROSS REFERENCE TO RELATED APPLICATION

This application is related to U.S. patent application entitled "DOT GROWTH SYSTEM AND METHOD," Ser. No. 13/547,765, "DOT GROWTH SYSTEM AND METHOD," Ser. No. 13/547,802, "ISOLATED HOLE DETECTION AND GROWTH," Ser. No. 13/547,875, "METHOD AND SYSTEM FOR ISOLATED HOLE DETECTION AND GROWTH IN A DOCUMENT IMAGE," Ser. No. 13/547,670, "METHOD AND SYSTEM FOR ISOLATED DOT DETECTION AND GROWTH IN A DOCUMENT IMAGE," Ser. No. 13/547,738, all filed concurrently with the present application, and all incorporated by reference herein in their entireties.

FIELD

The present application relates to a method and system for processing holes of an image for displaying and/or printing.

BACKGROUND

One common problem seen on xerographic marking engines is the inability to consistently or uniformly print small, isolated dots, for example, in binary bitmaps of an image. This causes image quality defects such as missing highlight tone and dotted lines. The same problem exists at the other end of the spectrum. Often in very high density regions, isolated holes cannot be reproduced by marking engines due to dot size or gain, making gray levels indistinguishable. To deal with marking engines of different characteristics, finer control of density adjustment is needed that can avoid inconsistent outputting of a single isolated dot or hole in an output image. Inconsistent and non-uniform isolated small dots or holes are hard to avoid resulting in artifacts in an output image.

SUMMARY

To achieve the desired growth behavior, one aspect of the present application provides a method for selectively processing isolated holes of an image to be printed by a printing device. The method includes detecting whether one or more pixels corresponding to an isolated hole in the image are in an off state, the off state defined by a lower binary logic level relative to a binary logic level corresponding to an on pixel. A first sum of pixels that are in an on state in a first pixel ring surrounding the one or more pixels corresponding to the isolated hole is determined when the one or more pixels in the isolated hole are detected to be in the off state. The first sum of pixels in the first pixel ring that are in the on state is compared with a first threshold sum. A first number of one or more pixels in at least a second pixel ring either comprising of or surrounding the one or more pixels corresponding to the isolated hole is turned off when the first sum of pixels in the on state is greater than the first threshold sum. The second pixel ring is inside the first pixel ring. The isolated hole including the turned off first number of pixels in the second pixel ring is outputted on a printable medium as an output image.

One aspect of the invention provides a method for selectively processing isolated holes of an image to be printed by a printing device. The method includes detecting whether one

2

or more pixels corresponding to an isolated hole in the image are in an off state, the off state defined by a lower binary logic level relative to a binary logic level corresponding to an on pixel. One or more pixel distances of one or more pixels in a turned off state nearest to the one or more pixels corresponding to the isolated hole is determined. Each pixel distance is compared to a threshold pixel distance. A first number of one or more pixels either comprising of or surrounding the detected one or more pixels is turned off based upon the comparing such that the turning off is carried out when one or more of the pixel distances are greater than the threshold pixel distance for outputting the isolated hole using an image output device.

One aspect of the invention provides a method for selectively processing isolated holes of an image to be printed by a printing device. The method includes detecting whether one or more pixels corresponding to an isolated hole in the image are in an off state, the off state defined by a lower binary logic level relative to a binary logic level corresponding to an on pixel. A sum of pixels, corresponding to a sum of holes different from the isolated hole, that are in a turned off state in at least a half scan line in one of a fast scanning and a slow scanning direction of the image is determined. The sum of pixels is compared to a threshold sum. At least a first number of one or more pixels in at least a pixel ring comprising or surrounding the detected one or more pixels corresponding to the isolated hole is turned off when the sum of turned off pixels is less than the threshold sum for outputting the isolated hole using an image output device.

Another aspect of the present application provides a system for selectively processing isolated holes of an image to be printed by a printing device. The system includes one or more processors. The one or more processors are configured to detect whether one or more pixels corresponding to an isolated hole in the image are in an off state, the off state defined by a lower binary logic level relative to a binary logic level corresponding to an on pixel, determine a first sum of pixels that are in an on state in a first pixel ring surrounding the one or more pixels corresponding to the isolated hole when the one or more pixels in the isolated hole are detected to be in the off state, compare the first sum of pixels in the first pixel ring that are in the on state with a first threshold sum, turn off a first number of one or more pixels in at least a second pixel ring either comprising of or surrounding the one or more pixels corresponding to the isolated hole when the first sum of pixels in the on state is greater than the first threshold sum, wherein the second pixel ring is inside the first pixel ring, and output the isolated hole including the turned off first number of pixels in the second pixel ring on a printable medium as an output image.

Yet another aspect of the present application provides a computer readable medium having stored thereon instructions for selectively processing isolated holes of an image to be printed by a printing device. The machine executable code when executed by at least one processor causes the processor to detect whether one or more pixels corresponding to an isolated hole in the image are in an off state, the off state defined by a lower binary logic level relative to a binary logic level corresponding to an on pixel, determine a first sum of pixels that are in an on state in a first pixel ring surrounding the one or more pixels corresponding to the isolated hole when the one or more pixels in the isolated hole are detected to be in the off state, compare the first sum of pixels in the first pixel ring that are in the on state with a first threshold sum, turn off a first number of one or more pixels in at least a second pixel ring either comprising of or surrounding the one or more pixels corresponding to the isolated hole when the first sum of

pixels in the on state is greater than the first threshold sum, wherein the second pixel ring is inside the first pixel ring, turn off a second number of pixels in the first pixel ring when the first sum of pixels in the on state is greater than the first threshold sum, and output the isolated hole including the turned off first number of pixels in the second pixel ring on a printable medium as an output image.

Other objects, features, and advantages of the present disclosed technology will become apparent from the foregoing detailed description, the accompanying drawings, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments will now be disclosed, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, in which:

FIG. 1 illustrates a block diagram of a system for processing an input digital image for hole growth, according to an aspect of the present disclosure;

FIG. 2A illustrates a context window, according to an aspect of the present disclosure;

FIG. 2B illustrates an example set of patterns or templates for isolated hole detection, according to an aspect of the present disclosure;

FIG. 3 illustrates of a flowchart of method for density control based isolated hole growth, according to an aspect of the present disclosure;

FIG. 4 illustrates a flowchart of another method for density control based isolated hole growth, according to an aspect of the present disclosure;

FIG. 5 illustrates a flowchart for a scenario when holes are grown based on density control, according to an aspect of the present disclosure;

FIG. 6 illustrates a method for percentage control based isolated hole growth, according to an aspect of the present disclosure; and

FIG. 7 illustrates an exemplary plot showing different values for enabling pixels for hole growth in an output image, according to an aspect of the present disclosure.

DETAILED DESCRIPTION

As used in this disclosure, an “image” is a pattern of physical light that in digital image processing and xerographic applications is converted to a two-dimensional array of data. Such data could be multi-bit or binary. Alternatively, the image may be defined using additional dimensions for different planes or components of the image. For example, a monochrome image has one color plane and a color image has three or four color planes. Example embodiments disclosed herein relate to both monochrome as well as color images. An image may include characters, words, and text as well as other features such as graphics, including pictures. An image may be divided into “segments,” each of which is itself an image. A segment of an image may be of any size up to and including the whole image.

An item of data can be used to define an image when the item of data includes sufficient information to produce the image. For example, a two-dimensional array can define all or any part of an image, with each item of data in the array providing a value indicating the color of a respective location of the image. Likewise, one or more “scanlines” can be used to define an image. A scanline divides an image into a sequence of (typically horizontal) strips. A scanline can be further divided into discrete pixels for processing in a com-

puter, xerographic, or printing system. This ordering of pixels by rows is known as raster order, or raster scan order.

Each location in an image may be called a “pixel.” In an array defining an image in which each item of data provides a value, each value indicating the color of a location may be called a “pixel value”. Each pixel value is a bit in a “binary form” of an image, a gray scale value in a “gray scale form” of an image, or a set of color space coordinates in a “color coordinate form” of an image, the binary form, gray scale form, and color coordinate form each being a two-dimensional array defining an image. A “central pixel” is not literally the center pixel in a region, rather the term describes a target pixel in a scanline being a single pixel or having a plurality of pixels. It will be appreciated that many or all of the pixels become the “central” or “target” pixel during the process of enhancing an entire image. Generally, the pixels make up individual features of the image. A binary pixel can take on two values: a 1 or a 0, 1 meaning ON and 0 meaning OFF. Specifically, one or more pixels that are ON and are contiguous or in close vicinity of each other define one or more dots that are to be printed by a printing device. Similarly, one or more pixels that are OFF and are contiguous or in close vicinity of each other define one or more holes that are to be printed by a printing device. The illustrated aspects of this disclosure relate generally to a system, a method, and a computer readable medium having stored thereon instructions for selectively processing isolated holes of an image to be printed by the printing device. In some aspects of the disclosure, one or more pixels may make a hole, e.g., an isolated hole as described herein.

The term “ON state” of a pixel is defined with respect to the pixel having a binary logic level higher than that of a pixel with a lower binary logic level. For example, a pixel that is at a “1” level is in an ON state as compared to a pixel at a “0” binary level or an “OFF state.” The ON and OFF states of the pixels can be stored in a register in a memory device, although forms of physical storage may be used.

The term “data” refers herein to physical signals that indicate or include information. When an item of data can indicate one of a number of possible alternatives, the item of data has one of a number of “values.” For example, a binary item of data, also referred to as a “bit,” has one of two values, interchangeably referred to as “1” and “0” or “ON” and “OFF” or “high” and “low.” An N-bit item of data has one of 2^N values, where N is an integer value. A “multi-bit” item of data is an item of data or signal that includes more than one bits. The bits of a binary number are ordered in sequence from Most Significant Bit (MSB) to Least Significant Bit (LSB) or vice versa. As used herein, “left” and “leftward” arbitrarily refer to a direction toward an MSB in sequence while “right” and “rightward” arbitrarily refer to a direction toward an LSB in sequence.

The term “data” includes data existing in any physical form, and includes data that are transitory or are being stored or transmitted. For example, data could exist as electromagnetic or other transmitted signals or as signals stored in electronic, magnetic, or other form.

An item of data relates to a part of an image, such as a pixel or a larger segment of the image, when the item of data has a relationship of any kind to the part of the image. For example, the item of data could define the part of the image, as a pixel value defines a pixel; the item of data could be obtained from data defining the part of the image; the item of data could indicate a location of the part of the image; or the item of data could be part of a data array such that, when the data array is mapped onto the image, the item of data maps onto the part of the image.

5

An operation performs “image processing” when it operates on an item of data that relates to part of an image. A “neighborhood operation” is an image processing operation that uses data relating to one part of an image to obtain data relating to another part of an image.

Pixels are “neighbors” or “neighboring” within an image when there are no other pixels between them or if they meet an appropriate criterion for neighboring. For example, using a connectivity criterion if the pixels are rectangular and appear in rows and columns, each pixel has a total of 8 neighboring pixels contiguous with the pixel of interest.

Another criterion for defining a “neighborhood” includes selecting a threshold distance between two pixels that are enabled or in an ON state for printing or display, as discussed below. Yet another criterion includes counting a threshold number of pixels in an $s \times t$ window surrounding the pixel of interest, s and t each being integers.

Another criterion for defining a “neighborhood” includes selecting a threshold distance between two pixels that are in an OFF state or enabled for printing or display as a hole, as discussed below.

An “image input device” is a device that can receive an image and provide an item or items of data defining a version of the image. A desktop “scanner” is an example of an image input device that receives an image by a scanning operation, such as by scanning a document. The resulting scanned document will have an input density of pixels. Scanning is carried out using, for example, a scanning bar in the image input device. The scanning bar scans the input image on a line by line basis. The direction in which the scanning bar scans the image is termed as a “fast scan” direction at the beginning of each scanline of the image. A second direction is termed as a “slow scan” direction that corresponds to a direction of movement of a printable medium (e.g., sheet(s) of printing paper) storing the image. The adjectives “fast” and “slow” refer to relative speed of movement of the scan bar and the printable medium.

An “image output device” is a device that can receive an item of data defining an image and provide the image as output. A “display” and a “laser printer” are examples of image output devices that provide the output image in human viewable form, although any type of printing device known to one of ordinary skill in the art may be used. The resulting output image will have an output density of pixels. The visible pattern presented by a display is a “displayed image” or simply “image” while the visual pattern rendered on a substrate by the printer is a “printed image”. The output image is printed using movement of one or more components in the image output device.

“Circuitry” or a “circuit” is any physical arrangement of matter that can respond to a first signal at one location or time by providing a second signal at another location or time. Circuitry specifically includes logic circuits existing as interconnected components, programmable logic arrays (PLAs) and application specific integrated circuits (ASICs). Circuitry “stores” a first signal when it receives the first signal at one time and, in response, provides substantially the same signal at another time. Circuitry “transfers” a first signal when it receives the first signal at a first location and, in response, provides substantially the same signal at a second location.

“Memory circuitry” or “memory” is any circuitry that can store data, and may include local and remote memory and input/output devices. Examples include semiconductor ROMs, EPROMs, EEPROMs, RAMs, and storage medium access devices with data storage media that they can access. A “memory cell” is memory circuitry that can store a single unit of data, such as a bit or other n -ary digit or an analog value.

6

“User input circuitry” or “user interface circuitry” is circuitry for providing signals based on actions of a user. User input circuitry can receive signals from one or more “user input devices” that provide signals based on actions of a user, such as a keyboard, a mouse, a joystick, a touch screen, and so forth. The set of signals provided by user input circuitry can therefore include data indicating mouse operation, data indicating keyboard operation, and so forth. Signals from user input circuitry may include a “request” for an operation, in which case a system may perform the requested operation in response.

For purposes of this disclosure, and not by way of limitation, an “isolated hole” is generally defined as a hole that satisfies one or more criteria such as how close that hole is to the nearest pixel or group of pixels corresponding to another hole. Similarly, an isolated hole may be defined as a hole that has a threshold number of holes surrounding that hole that are enabled for printing as a hole. Other criteria for defining an isolated hole may be used too. The system may be generically considered a printing system having an input image that is processed for printing or displaying as an output image. The input image has an input density of holes with one or more pixels in an OFF state, and an input density of dots with one or more pixels in an ON state making up the input image. Correspondingly, the output image has an output density or a desired density of holes and dots making up the output image. Typically, input and output densities are different since input density of holes and dots is optimized for removing artifacts to result in the output density of holes and dots, respectively.

“Hole growth” generally refers to a process in which a size of an isolated hole that does not meet a threshold size criterion suitable for outputting is increased. For example, such increase in size may be reflected by selecting one or more pixels in a neighborhood of the detected hole and disabling those pixels for outputting or printing.

Referring to FIG. 1, there is depicted a partly functional and partly schematic diagram of an aspect of the present technology. An aspect of the present disclosure is employed as a system **100** for processing an input digital image generated and/or provided by an Image Input Terminal (IIT) **106** to optimize growth of isolated holes therein. By way of example only, input image can be provided as a plurality of binary data signals representing, for example, the text, halftone and graphic image regions that make up a source document from which the input image was generated, or is being generated in real-time. That is, the input image may be produced as a digitized representation of a hardcopy document, for example, by scanning on a scanner. As illustrated in FIG. 1, the source of the digital image (interchangeably referred to herein as “input image”) may be any IIT, where the image is passed to or stored in memory **110**. Alternatively, the term “input image” may be used to describe an image that is input to a hole growth system **114**, described below. Memory **110** may be suitable for the storage of the entire image or it may be designed to store only a portion of the image data (e.g., several rasters or fast-scan lines). More specifically memory **110** stores data that is representative of the imaging areas in the digital image. Memory **110** can comprise computer readable media, namely computer readable or processor readable storage media, which are examples of machine-readable storage media. Computer readable storage/machine-readable storage media can include volatile, nonvolatile, removable, and non removable media implemented in any method or technology for storage of information, e.g., computer readable/machine-executable instructions, data structures, program modules, or other data, which can be obtained and/or executed by one or more processors.

Memory **110** is a generic term and it may comprise a single memory or a plurality of separate memories. Such memories refer to computer readable media, and may be of the type that are removable from the camera, or of the type that are integrated into IIT **106** (e.g., a camera). Examples of such memory may include, but are not limited to flash memory, USB thumb drives, a memory stick, CDs, DVDs or other optical recording media, floppy disks or other magnetic recording media, or any other type of memory now known or later developed. Where memory **110** comprises a single memory, the input image may be stored separately in memory **110**. Likewise, the lower resolution images could be stored to a first memory and the higher resolution images could be stored to a physically separate second memory.

The data may be extracted from memory **110** on a raster basis or on a pixel-by-pixel basis for use by the subsequent components or steps. More specifically, a pixel region window block **112** (referred to as window **112**) serves to select some or all pixels within a region of the image (accesses or extracts from memory **110**), so as to make the data for the respective pixels available for processing. It will be appreciated that while described as a static system, the disclosed embodiment is intended to continuously operate on pixel data in a “streaming” fashion, and that window **112** may be any suitable apparatus or methodology that allows access to a plurality of pixels.

As described herein, window **112** determines different regions of the digital image, the regions including a plurality of imaging areas. Such regions are suitable for optimizing and controlling growth of isolated holes therein. According to one aspect of the disclosure, such windowing may include a plurality of fast-scan data buffers, wherein each buffer contains a plurality of registers or similar memory cells for the storage of image data therein, with the data being clocked or otherwise advanced through the registers. The number of registers is dependent upon the “horizontal” (fast-scan) window size and/or line width, whereas the number of buffers is dependent upon the “vertical” (slow-scan) window size. As will be appreciated, the window size is dependent upon a context, as discussed in FIG. **2** below, that is required to implement the particular image adjustment desired and the level of addressability of the imaging areas (higher levels of addressability will inherently result in more data stored to provide the required context). While one windowing technique has been generally described, it will be appreciated that similar means may be implemented using hardware and/or software to point/access a memory device, so that data for selected imaging areas may be accessed, rather than having the data separately stored in a buffer. It will also be appreciated that alternative configurations may be employed for the buffer. For example, a single, long, buffer may be employed, where image data is simply clocked through the buffer. Thus the various alternatives all employ some form of memory for storing image data representing image areas in at least one region of the image.

Output from window **112** is provided to hole growth system **114**. Hole growth system **114** includes one or more look-up tables (LUTs) **116**, a hole growth module **124** communicably coupled to a pseudo-random number generator **122** (interchangeably referred to as a random number generator **122**) and a density control module **125** as shown by example connecting arrows, a processor **124**, a local memory **126**, and other logic circuitry (not shown). In one alternative aspect of this disclosure, LUTs **116** may be a part of local memory **126**. Hole growth system **114** carries out various functions and methods related to detection and growth of isolated holes in an input image provided by IIT **106**, and received by hole

growth system **114** as a bitmap of pixels from window **112** and provided to an Image Output Terminal (IOT) **128** as an input for display and/or printing purposes. Hole growth module **124**, random number generator **122**, and density control module **125** may be implemented using hardware (e.g., memory, registers, circuits). Alternatively, hole growth module **124**, random number generator **122**, and density control module **125** may be software modules with code residing upon tangible computer readable medium to carry out various features and functions related to hole detection and growth. Further, hole growth module **124**, random number generator **122**, and density control module **125** may be a combination of hardware and software, as may be contemplated by one of ordinary skill in the art. By way of example only, and not by way of limitation, processor **124** can be conveniently implemented using one or more general purpose computer systems, microprocessors, digital signal processors, micro-controllers, application specific integrated circuits (ASIC), programmable logic devices (PLD), field programmable logic devices (FPLD), field programmable gate arrays (FPGA) and the like, programmed according to the teachings as described and illustrated herein, as will be appreciated by those skilled in the computer, software and networking arts. For example, processor **124** can be a PENTIUM® processor provided by Intel Corporation, Santa Clara, Calif. Further, although a single processor is illustrated, more than one processors coupled by a bus may be used. Local memory **126** is similar to memory **110** and therefore, structure of local memory **126** is not being described in detail.

After processing at hole growth system **114** (e.g., using processor **124**), input image is transformed into an output image for printing and/or displaying at IOT **128**. IOT **28** comprises a display unit (not shown) for displaying output image, although in alternative embodiments, IOT **128** could also print the output image (e.g., when IOT **128** is at a print end of a copier). As will be appreciated, additional LUTs and storage and logic circuitry may be used for producing the output image at IOT **128**.

Referring to FIG. **2A**, a context window **202** with respect to a fast scan and a slow scan direction is shown. Context window **202** includes a center pixel or a target pixel **204**, an inner row or ring of pixels **206**, and an outer row or ring of pixels **208** surrounding or in the neighborhood of center pixel **204**. In one aspect, context window **202** is a part of an input image that comprises a plurality of scanlines that are further made of a plurality of context windows, similar to context window **202**. Pixels shown in context window **202** can be represented by at least one binary value (“0” or “1”). A high binary value (e.g., “1”) indicates that the pixel is enabled for outputting (printing and/or displaying), and a low binary value (e.g., “0”) indicates that the pixel will not be printed or displayed in an output image outputted by IOT **128**. Therefore, context window **202** may be represented as a matrix (or other known data structure) comprising a bitmap of binary values stored, for example, in a register in memory **110**. In the example shown in FIG. **2**, inner ring **206** is a 3×3 pixel ring where pixels are denoted as “N,” “S,” “E,” “W,” “NE,” “NW,” “SE,” and “SW” in terms of their location relative to center pixel **204**. The pixels in the inner 3×3 window are used to form an index to a programmable 256-entry 6-bit look up table in look up tables **116** (e.g., LUT1). Such an index can be defined as: index={NW, N, NE, W, E, SW, S, SE}, although other formats for defining the index may be used. For example, the order of pixels forming the index may be changed. The look up table indexed by the index is used for detection of center pixel **204** at beginning of each scanline of the input image. For example, the MSB of the 6-bit detection look-up table (“de-

tectionLUT”) determines a region of the input image to which context window **202** belongs. The remaining 5 bits of the 6-bit detectionLUT are used to obtain one or more matching templates that will be used to output image on IOT **128** and will form an output image context window that may replace context window **202**. For example, when a value of the remaining 5-bits is greater than 31, center pixel **204** is skipped and is not detected for hole growth of the hole in the input image corresponding to either a center pixel **204** or any of its adjacent neighboring pixels. In such a scenario, context window **202** will be unchanged in the output image. As will be appreciated by one of ordinary skill in the art, additional criteria may be applied toward determining whether or not center pixel **204** will be detected for hole growth. Such additional criteria for inner ring **206** pixel values are disclosed in related U.S. patent application entitled “METHOD AND SYSTEM FOR ISOLATED HOLE DETECTION AND GROWTH IN A DOCUMENT IMAGE,” Ser. No. 13/547,670, filed concurrently with the present application, the disclosure of which is incorporated by reference herein in its entirety. An example of such criteria is described in FIG. 2B.

Referring to FIG. 2B, an exemplary set of patterns **200** may be used in isolated hole detection. For example, if the programmable hole growth factor is set to four, then the pixels within the context window **202** are checked against pixel patterns **210-272** of a third tier of patterns shown in FIG. 2B. That is, twenty five more patterns **222-272**, or a total of thirty one patterns **210-272** are checked if the hole growth factor is set to four.

All the pixel patterns **210-272** of the third tier have a hole growth factor of four. The pixel patterns **210-272** of the third tier provide the capability of growing a one-pixel hole, a two-pixels hole or a three-pixels hole to a four-pixels hole. For example, the pixel patterns **210**, **212**, and **222** provide the capability of growing a one-pixel hole to a four-pixels hole. The pixel patterns **214-230** provide the capability of growing two-pixels hole to four-pixels hole. The pixel patterns **232-268** provide the capability of growing three-pixels hole to four-pixels hole. There will be no pixel hole growth when the programmable hole growth factor is set to four and a four-pixels hole is present in the context window. Additional examples of templates used for hole detection may be found in related U.S. patent application entitled “METHOD AND SYSTEM FOR ISOLATED HOLE DETECTION AND GROWTH IN A DOCUMENT IMAGE,” Ser. No. 13/547,670, filed concurrently with the present application, the disclosure of which is incorporated herein by reference in its entirety.

Referring back to FIG. 2A, in the example shown, the pixels from outer ring **208** of the 5x5 window are arranged in a 16-bit array as {R0, R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15}, although other numbers and/or other orderings of pixels may be used. In one aspect of the disclosure, a number of “ON” pixels surrounding current pixel **204** are counted using processor **124**. The “ON” state pixels correspond to one or more dots in the input image that are already enabled. Although the counting is carried out for outer ring **206** in 5x5 context window **202**, any window of size sxt within a neighborhood of current pixel **204** may be used, where s and t are integers. By way of example only, the 16-bit array may be stored in a register of memory **110**. This is to record the density of ON pixels in the neighborhood of the isolated hole i.e. the graylevel value surrounding the isolated hole.

Various aspects of the present disclosure effectively deal with a variety of artifacts introduced in growth of holes in an image to be outputted by IOT **128**, and to better accommodate

marking engines of different characteristics by using finer and more flexible control of hole growth. Some examples of such artifacts include missing groups of scanline in the output image, and lower than a desired density of dots or holes in each scanline of the output image outputted by IOT **128**. As discussed with respect to flowcharts **300-600** in FIGS. 3-6 below, the enabling of hole growth in various regions of an image (e.g., highlights, known to one of ordinary skill in the art) is determined by using percentage control of a number of pixels enabled for printing as a hole in conjunction with output density control of different regions of the image based upon an input density of the input image obtained from IIT **106**. The image is subsequently stored in memory **110** as an n-dimensional image array, n being an integer greater than zero (0). Such a percentage can either be a function of the number of holes not grown in the neighborhood of the current pixel, or it can be controlled using a random number generator. In some aspects of the disclosure, the percentage can be a function of both a random number and a number of holes not grown. As can be appreciated, the output image at IOT **128** will have hole density dependent upon the technique or the combination of techniques used.

The various functions of the elements of system **100** may be controlled by a central microprocessor (e.g., processor **124**), and the instructions to carry out the exemplary methodology may be embedded in a chip, or may be loaded into a memory associated with the microprocessor as software. Such features and functions are illustrated and described with reference to the flowcharts herein, and the steps in the flowcharts are by way of example only and not by way of limitation. For example, steps may be interchanged, combined, or added to implement various features and functionalities of the technology in this disclosure. The particular manner in which the elements of system **100** are controlled and the method or process of the flowcharts is performed is not particularly critical, and other control structure or architecture may be used for system **100**.

Referring to FIG. 3, an example process for density control of output holes based upon the number of ON pixels in the neighborhood of detected isolated holes in an input image is described using flowchart **300**.

In block **302**, processor **124** counts a number of pixels that are in an ON state in a neighborhood of center pixel **204**. For example, processor **124** can count a number of ON pixels in outer ring **208** surrounding center pixel **204**. Alternatively, processor **124** can count a total number of ON pixels in an sxt neighborhood of center pixel **204**, where s and t are integers. The number determined from such counting is stored in local memory **126** of hole growth system **114** as a variable (“ring16”). The number of pixels in an ON state in the neighborhood of current pixel **204** define an input density of the input image for each pixel of each scanline making up the input image.

In block **304**, processor **124** determines if current center pixel **204** was detected to be grown by a hole detection and growth algorithm. For example, processor **124** may check such detection using FIG. 2B, although any other form of hole detection and growth algorithm may be used. If yes, the flow proceeds to block **306**. If no, the flow proceeds to block **308**.

In block **306**, processor **124** determines if the value of ring16 variable determined in block **302** is greater than or equal to a programmable parameter or threshold value (“TH_SUM_ON”), the flow proceeds to block **310**. For example, value of ring16 may be based on pixels in a first ring (e.g., outer ring **208**) or a second ring (e.g., inner ring **206**), although other neighborhoods beyond such rings or rows may be used. If not, the flow proceeds to block **308**.

11

In block 308, if processor 124 determines that center pixel 204 was not detected as a pixel for hole growth, current center pixel is left as is in its current state. Such marking comprises updating registers and flags stored in local memory 126 indicating that center pixel 204 will not be used for hole growth. In one example, processor 124 may revert to step 302 for a next pixel after block 308.

In block 310, current center pixel 204 is used for hole growth by turning OFF a pixel value. Such enabling comprises marking pixels neighboring center pixel 204 to an OFF state resulting in an enlarged hole comprising one or more pixels that may include center pixel 204 and additional pixels surrounding center pixel 204 (e.g., one or more contiguous or non-contiguous pixels from inner ring 206 and outer ring 208). Corresponding updates may be made to registers and flags stored in local memory 126 indicating a growth of a hole corresponding to center pixel 204.

Referring to FIG. 4, an example process for density control of output holes based upon grown isolated holes in the neighborhood of the current isolated hole (e.g., center pixel 202) in an input image is described using flowchart 400.

In block 402, at start of each scanline of the input image, processor 124 sets an n-bit register in local memory 126 to zero, n being a positive integer value. For example, a register used for bit shifting purposes (“HoleBitShift”) may be set to all zeros. In one example, 8-bit register HoleBitShift is used to keep track of the pixels turned OFF in the fast scan direction, although other sizes of HoleBitShift register in other scan directions may be used.

In block 404, processor 124 determines if current center pixel 204 was detected to be grown by a hole detection and growth algorithm. For example, processor 124 may check such detection using FIG. 2B, although any other form of hole detection and growth algorithm may be used. If yes, the flow proceeds to block 406. If not, the flow proceeds to block 412.

In block 406, processor 124 determines if value of HoleBitShift register is less than or equal to a programmable parameter (“LocalHoleDensity_TH1”). If yes, the flow proceeds to block 408, and if no, the flow proceeds to block 412.

In one variation of the process shown by flowchart 400, after block 406, the flow proceeds to block 407 including blocks 407a and 407b. In block 407a, when the condition in block 406 is satisfied, processor 124 determines a sum of all ON bits in HoleBitShift register and stores the sum in a variable (“SumHoles”). In block 407b, processor 124 determines if this sum stored in variable SumHoles is less than or equal to the local density threshold variable “LocalHoleDensity_TH2”. If yes, the flow proceeds to block 412, and if not, the flow proceeds to block 408.

In block 408, current center pixel 204 is grown as a hole by turning OFF a pixel value. Such enabling comprises marking pixels neighboring center pixel 204 to an OFF state resulting in an enlarged hole comprising one or more pixels that may include center pixel 204 and additional pixels surrounding center pixel 204 (e.g., one or more contiguous or non-contiguous pixels from inner ring 206 and outer ring 208). Corresponding updates may be made to registers and flags stored in local memory 126 indicating a growth of a hole corresponding to center pixel 204.

In block 410, the HoleBitShift register is updated by right shifting a binary “1” into HoleBitShift register.

In block 412, when the hole is not to be grown, the HoleBitShift register is updated by right shifting a binary “0” into HoleBitShift register.

Referring to FIG. 5, an example process for density control of output holes based upon density of grown holes in the

12

current scanline, which would be the scanline of the current detected isolated hole in an input image is described using flowchart 500.

In block 502, at start of each scanline of the input image, a counter (“OnHoleCounter”) is set to zero. In one example, such a counter may be a 4 bit counter with binary values stored therein, although other types of counters implemented using processor 124 and local memory 126 may be used.

In block 504, processor 124 determines if current center pixel 204 was detected to be grown by a hole detection and growth algorithm. For example, processor 124 may check such detection using FIG. 2B, although any other form of hole detection and growth algorithm may be used. If yes, the flow proceeds to block 510. If not, the flow proceeds to block 506.

In block 506, center pixel 204 is not marked for growth and in block 508, processor 124 leaves counter OnHoleCount in current state without altering its contents.

In block 510, when center pixel 204 is determined to be selected for hole growth, processor 124 determines whether or not the value stored in counter OnHoleCount is less than or equal to an output density threshold (“OutputHoleDensity_TH”). In one example, OutputHoleDensity_TH may be a 5-bit programmable register. If the counter value is less than the threshold, the flow proceeds to block 512. If the counter value is not less than the threshold, the flow proceeds to block 516.

In block 512, current center pixel 204 is grown by turning OFF a pixel value. Such enabling for holegrowth comprises marking pixels neighboring center pixel 204 to an OFF state resulting in an enlarged hole comprising one or more pixels that may include center pixel 204 and additional pixels surrounding center pixel 204 (e.g., one or more contiguous or non-contiguous pixels from inner ring 206 and outer ring 208). Corresponding updates may be made to registers and flags stored in local memory 126 indicating a growth of a hole corresponding to center pixel 204.

In block 514, after current center pixel 204 is grown, processor 124 increments counter OnHoleCount by one to indicate that current pixel 204 was grown as a hole.

In block 516, when the condition in block 510 is not satisfied, processor 124 resets counter OnHoleCount to zero.

Flowchart 300 and 400 offer local density control for each pixel whereas flowchart 500 provides density control for a full scanline. Further, flowchart 300 checks the input density of the image whereas flowcharts 400 and 500 look at the output density of the image. The methodologies disclosed in flowcharts 300-500 modify the desired output density based on the input and/or output holegrowth density in some local or global neighborhood of the current detected isolated hole to obtain an optimal output image for printing and/or display by IOT 128.

It is to be noted that the bit depths specified for the registers described above are typical values and other values are possible. By setting the programmable thresholds accordingly, only flowchart 300 may be carried out by processor 124, only flowchart 400 may be carried out by processor 124, or only flowchart 500 may be carried out by processor 124. Further, processor 124 may carry out any combination of the three adjustments of hole density illustrated by the processes of flowcharts 300-600. Furthermore, although flowcharts 400 and 500 are carried out by processor 124 in the fast scan direction only to keep the implementation simple, other variant implementations in other scan directions (e.g., slow scan direction) may be additionally or optionally carried out by processor 124. The adjustments described by the processes of flowcharts 300-500 can be invoked at different stages of hole growth.

13

FIG. 6 illustrates an example process for enabling hole growth in various regions on the input image (e.g., in high-light regions) by using a percentage control method described using flowchart 600.

In block 602, at start of each scanline of the input image, initialization of various counters and registers in memory 110 and/or local memory 126 is carried out. For example, a counter that counts a number of pixels that were initially enabled for holegrowth based on some isolated hole detection and growth algorithm but were later disabled for hole growth is initialized to a number "0" at start of each scanline ("HolesNotGrown=0"). Likewise, location of a first center pixel or target pixel is recorded into a variable identifier "HolesNotGrownLocation" for which a binary holegrowth flag was initially set but is later reset to a binary "0". Likewise, a register (e.g., a "HoleShift" register) storing density control values is initialized to zero. Density control value is used to control the local density of the holes grown in some neighborhood of the current pixel (e.g., center pixel 202).

In block 604, for each pixel in the scanline (e.g., current center pixel 204), processor 124 determines whether or not the pixel is in an OFF state, or is enabled for printing as a hole. For example, processor 124 may determine whether or not a hole corresponding to the current pixel is to be grown. This may be indicated by setting a flag (e.g., "HoleGrowthFlag=1"). If not, processor 124 in hole growth system 114 goes to the next pixel, as indicated in block 606 and checks for the condition in block 604 again for the next pixel. As noted earlier, one or more pixels (e.g., center pixel 204) can correspond to one or more holes in the input image. Holes in the input image determine an input density of holes (and therefore, pixels). Likewise, the output image has a corresponding output density of holes that is desired to overcome or remove the artifacts in the input image.

In block 608, processor 124 counts a number of pixels that are in an ON state in a neighborhood of center pixel 204. For example, processor 124 can count a number of ON pixels in outer ring 208 surrounding center pixel 204 and store this number in a variable ("ring16"). Alternatively, processor 124 can count a total number of ON pixels in an $s \times t$ neighborhood of center pixel 204, where s and t are integers. The number determined from such counting is stored in local memory 126 of hole growth system 114. The number of pixels in an ON state in the neighborhood of current pixel 204 define an input density of the input image for each pixel of each scanline making up the input image. This number is then used to obtain values between -2^m to 2^m in a look-up table discussed with respect to block 614 below. Upon determining the number of ON pixels, processor 124 carries out the processes of blocks 610, 612, and 614 in parallel, although in some examples these processes may be carried out in series.

In block 610, using random number generator 122, processor 124 generates a random number. In one aspect of this disclosure, the generated random number is in a finite range of -2^m to 2^m , where m is an integer, although other ranges may be used. An exemplary value of m is 9, although other values may be used. It is to be noted that any technique of generating random numbers known to those of ordinary skill in the art could be used, and the present disclosure is not limited to any particular technique of generating random numbers. For example, the random number could be a "true" random number or a pseudo-random number, and may be generated by one or more computational techniques known to one of ordinary skill in the art implemented using processor 124.

In block 612, the value of ring16 from block 608 is used as an index to one or more LUTs 116 to output a hole density

14

control value that is used as a threshold against the density of grown holes in some neighborhood of the current isolated hole (e.g., center pixel 202).

In block 614, the number of ON pixels counted in block 608 is used to generate a percentage value for enabling a number of pixels for hole growth in a plurality of pixels making up the scanline. Such percentage value may be obtained from a look-up table mapping values from the look-up table (LUT) that maps values between values of "ring16" and -2^m to 2^m for percentage control. The output of the LUT which are the percentage control values determine a percentage of enabled pixels for holegrowth out of a total number of enabled pixels for hole growth in the scanline that will be selectively enabled for hole growth by hole growth system 114, and outputted by IOT 128. An exemplary table is shown as Table I below, although tables with other values may be developed:

TABLE I

Pixels in ON state in outer ring 208	LUTs 116 output Percentage control Values	Percentage of Pixels enabled for hole growth
16	-256	100
15	-192	87.5
14	-128	75
13	-64	62.5
12	0	50
11	64	37.5
10	128	25
9	192	12.5
0-8	256	0

For example, using the above table, if all pixels in the neighborhood of the current isolated hole detected and enabled for growth are in an ON state, a 100% of these enabled pixels will be grown as holes based on this criteria only, although additional criteria (as discussed below) may reduce the percentage value. Likewise, if 10 pixels in outer ring 208 are ON, then about 25% of pixels enabled for hole growth are selectively enabled in the output image outputted by IOT 128. As seen from Table I above, more than one (e.g., two or more) values for number of pixels in outer ring 208 that are in an ON state may correspond or map to the same percentage value of pixels that are to be enabled for hole growth in the output image. Further, it is to be noted that the selected percentage of pixels can be less than 100% indicating that not all pixels corresponding to one or more isolated holes will be grown. The flow proceeds to block 618.

In block 616, processor 124 compares if a number of holes that were enabled for hole growth based on some isolated hole detection and hole growth algorithm but were not grown in a past context with respect to current center pixel 204 is greater than or equal to a threshold number. If not, the flow proceeds to block 622. If yes, the flow proceeds to block 618.

In block 618, processor 124 determines if location of current center pixel 204 is less than or equal to a threshold distance from a location of the last hole that was supposed to be grown based on some isolated hole detection and growth algorithm but was not grown as discussed below in blocks 642 and 646. Processor 124 may carry out this determination by calculating an absolute value of the difference between a current center pixel 204 and a "HolesNotGrown" variable initialized in block 602. Alternatively or additionally, processor 124 may determine if the random number generated in block 610 is greater than the percentage value obtained from

15

Table I above. If either of these conditions in block 618 is true, the flow proceeds to block 620, else the flow proceeds to block 622.

In block 620, processor 124 sets a hole density value equal to a hole density control value obtained from block 612.

In block 622, processor 124 sets the hole density value equal to zero. Blocks 620 and 622 are used to perform density control for holes in two different ways.

The flow from blocks 620 and 622 then proceeds to block 624.

In block 624, processor 124 counts a number of ON bits in the HoleShift register of block 602. This count may be stored in a variable "HoleCount" in local memory 126.

In block 626, processor 124 determines if the value of variable HoleCount is greater than the value of the variable HoleDensityVal of blocks 620 and 622. If yes, the flow proceeds to block 634. If no, the flow proceeds to block 628.

In block 628, processor 124 sets the variable HolesNotGrown counter to zero.

In block 630, processor 124 sets a least significant bit (LSB) of HoleShift register to 1.

In block 632, processor 124 sets a HoleGrowthFlag to "1" indicating that a hole corresponding to the current pixel (e.g., center pixel 204) will be grown as a hole. The flow then proceeds to block 646.

In block 646, the parameter HolesNotGrownLocation is set to 0, indicating for the future detected holes in that scanline that a hole has been grown in some pre-defined neighborhood of the current detected hole. The flow then proceeds to block 606 via block 644 discussed below.

In block 634, processor 124 sets a least significant bit (LSB) of HoleShift register to "0".

16

In block 636, processor 124 sets a HoleGrowthFlag to "0" indicating that a hole corresponding to the current pixel (e.g., center pixel 204) will not be grown as a hole.

In block 638, processor 124 increments HolesNotGrown counter. The flow then proceeds to block 640.

In block 640, processor 124 determines if HolesNotGrownCounter is equal to "1". If yes, it indicates that a pixel in the neighborhood of the current detected hole is a first hole that was not grown as a hole and is detected as a result of any earlier hole growth logic previously applied on the current pixel (e.g., center pixel 204). The flow proceeds to block 642. If no, it indicates that further initialization in the current scanline is not needed and the flow goes to block 644.

In block 642, processor 124 sets a HoleNotGrownLocation variable to current center pixel 204's location.

In block 644, processor 124 carries out a left shift operation in the HoleShift register by 1 bit. The flow then goes back to block 606.

The processes described in flowcharts 300-600 may be summarized in Table II below.

Table II illustrates an example with various parameters, variables, and conditions discussed above in flowcharts 300-600. For example, for Table II, for ring16=16, LUT 116 implies HoleDensityValue=2, and LUT 116 Hole_PercentageVal=0 which means 50% of the pixels enabled for hole-growth based on a hole growth algorithm (such as those known to one of ordinary skill in the art) may be selectively enabled based on the examples of hole growth algorithm in accordance with an embodiment. Similarly, for ringNum=15, LUT 116 implies HoleDensityValue=1, and LUT 116 Hole_PercentageVal=68 means approximately 40% of the pixels enabled for holegrowth can be enabled for holegrowth based on examples of hole growth algorithm in accordance with an embodiment.

TABLE II

Registers/ Variables	Comments	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	
1. HoleGrowth Flag: 1/0 (Block 604)	Hole is to be grown for current center pixel 204 as dictated by a hole growth algorithm	1	0	1	0	1	0	0	1	0	1	0	0	1	0	1	0
2. Rand_No (Block 610)	Output of random number generator 122	-	6	-	-	2	1	-	-	2	1	-	-	89	10	20	60
3. Ring16 (Block 608)	Number of ON pixels in neighborhood of current pixel 204	16	1	1	1	1	1	1	1	1	1	1	15	15	15	15	15
4. HolesGrown	Number of holes grown in HoleShift register This is the HoleCount in block 624 from previous pixel	1	0	1	1	2	2	2	3	2	3	2	1	1	1	2	1
5. HoleNotGrown Location (Blocks 642, 646 from previous pixel)		0	N	N	0	0	0	0	0	N	N	N	N	N	0	0	N
6. HolesNotgrown Counter (Blocks 638, 628) again from previous pixel		0	1	0	0	0	0	0	1	1	2	2	2	0	0	1	1

TABLE II-continued

Registers/ Variables	Comments	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	
		N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
7. Pixel enabled for holegrowth because of random number (Block 618)	Is Rand_No>= PercentageVal	0	1	0	0	1	1	0	0	1	1	0	0	1	1	1	0
8. Pixel enabled for holegrowth with HoleNot grown logic (Block 618)	Is abs(current_pixel-HoleNot GrownLocation)<= threshold_distance	0	1	1	0	0	0	0	0	1	1	1	1	1	0	0	1
9. Holedensity (Blocks 620 and 622)	Will be set to either a 1 or 0 based on 7 and 8 above and block 616 HoleDensityvalue comes from the LUT which will be either a 2/1 in this case.	0	X	2	X	2	X	X	0	X	2	X	X	1	X	1	X
Holegrowth flag - updated value (Blocks 632, 636)	Will be turned OFF if HolesGrown> HoleDensity).	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0
HolesNotgrown Counter - updated value (Blocks 638, 628)	Will be updated based on block 626.	1	1	0	0	0	0	0	1	1	2	2	2	0	0	1	1
Holesgrown - updated value (Blocks 634, 630)	New value of number of counts in HoleShift register. Depending on whether it's LSB is set to a 1 or 0.	0	0	1	1	2	2	2	2	2	2	2	1	1	1	1	1
HoleNotGrown Loc - updated value (Blocks 646, 642)	New value based on block 626	N	N	0	0	0	0	0	N	N	N	N	N	0	0	N	N
									+	+	+	+	+			+	+
									7	7	7	7	7			14	14

For example, as shown in block 616, pixels N+7 and N+9 have an initial value of HoleGrowthFlag=1 coming from any hole detection algorithm. For pixel N+7, random number generated is less than HolepercentageVal (0 in this case for ring16=16) thus turning the HoleGrowthFlag OFF. For pixel N+9, random number generated>HolepercentageVal but number of holes grown in HoleCount (Block 626) is greater than the HoleDensityVal (which is 2 in this case-block 612), thus turning the HolegrowthFlag OFF. Pixel N+12 satisfies the conditions for random number as well as the local hole density (HoleCount) and will be grown only if HolesNotgrownCounter (item 6 in Table II which is 2 coming from the previous pixel)>=threshold (e.g., having a value of 1 in this example). Table II above shows that holes that were supposed to be grown using some known holegrowth algorithm are 7 out of a total of 16 in this example. (i.e., 7/16). Out of these 7 pixels enabled for holegrowth, 3 were selectively enabled as a result of HolesNotGrownCounter (3/16). Additionally, out of these 7 pixels enabled for holegrowth, 4 were selectively enabled as a result of random number generator (4/16) or (4/7), and out of these 7 pixels enabled for holegrowth, the total number of pixels selectively enabled were 5 (5/16) or (5/7). Thereafter, applying additional logic of hole density control discussed above, holes actually grown finally are three (3) in number, i.e., 3/7 or approximately 42.8% of total number of holes.

FIG. 7 illustrates a plot 700 showing flexible hole growth pattern based on one or more conditions described above as a function of a number (n) of pixels surrounding center pixels

204 that are in an ON state. Generally, plot 700 shows a percentage of pixels enabled in the output image for hole growth. The output density is adjusted based upon one or more methodologies illustrated in flowcharts 300-600 as discussed above. For example, line 702 in plot 700 shows percentage of pixels enabled for hole growth using random number generator 122 (e.g., in blocks 610-618). Line 704 illustrates further fine tuning by processor 124 to account for a number and distance of pixels that were enabled for hole growth based on some known hole growth algorithm but were not grown in a past context of context window 202, as discussed with respect to blocks 616 and 618 in FIG. 6 Likewise, line 706 shows additional fine tuning using the hole density control value discussed in FIG. 3-6. As can be seen in plot 700, depending on which technique or combination of techniques that are being used by processor 124 to adjust growth of isolated holes, a particular percentage of pixels in each scanline of the output image will be enabled. For example, if 1-2 pixels surrounding center pixel 204 are in an ON state in the input image, for the output image the number of pixels enabled for holegrowth will be in a range centered around 50% of total number of pixels in the scanline in one case, by way of example only and not by way of limitation. The range exists since processor 124 adjusts the percentage of pixels depending on which methodology shown in FIGS. 3-6 is used. If only a random number generator 122 is used by processor 124, then solid line (similar to line 702) closest to the 50% mark indicates the output hole density of the scanline. Likewise, if only holes not grown in a past context of

19

center pixel **204** is utilized by processor **124**, then chained line (similar to line **704**) indicates the output hole density of the scanline. However, since processor **124** may utilize all or more than one methodology, each resulting in a different output hole density, the final outputted scanline will have an output density that could be a fine tuned or modulated average of the output densities obtained by the methodologies described in FIGS. **3-6**. Further, it is to be noted that the ranges/margins of output percentage of pixels enabled for hole growth is for example purposes only and is not meant to be limiting.

The foregoing aspects of the disclosure have been provided as examples within the scope of the technology disclosed and should not be regarded as limiting. To the contrary, the present disclosure is intended to encompass all modifications, substitutions, alterations, and equivalents within the spirit and scope of the following claims.

What is claimed is:

1. A method for processing isolated holes of an image to be printed by a printer, comprising:

detecting whether one or more pixels corresponding to an isolated hole in the image are in an off state, the off state defined by a lower binary logic level relative to a binary logic level corresponding to an on pixel;

determining a first sum of pixels that are in an on state in a first pixel ring surrounding the one or more pixels corresponding to the isolated hole when the one or more pixels in the isolated hole are detected to be in the off state;

comparing the first sum of pixels in the first pixel ring that are in the on state with a first threshold sum;

turning off a first number of one or more pixels in at least a second pixel ring either comprising of or surrounding the one or more pixels corresponding to the isolated hole when the first sum of pixels in the on state is greater than the first threshold sum, wherein the second pixel ring is inside the first pixel ring; and

outputting the isolated hole including the turned off first number of pixels in the second pixel ring on a printable medium as an output image.

2. The method of claim **1**, wherein both the first and the second pixel ring comprise pixels in at least one of a fast scanning and a slow scanning direction of a scanning device, and wherein the first and the second pixel rings together define a two-dimensional neighborhood of the isolated hole with one dimension corresponding to the fast scanning direction and another dimension corresponding to the slow scanning direction.

3. The method of claim **1** further comprising:

determining one or more pixel distances of one or more pixels in a turned off state nearest to the one or more pixels corresponding to the isolated hole;

comparing each pixel distance to a threshold pixel distance; and

turning off the first number of one or more pixels in the second pixel ring based upon the comparing such that the turning off is carried out when one or more of the pixel distances are greater than the threshold pixel distance.

4. The method of claim **1** further comprising:

determining using an n-bit counter device a second sum of pixels that are in a turned off state in an $m \times 1$ pixel window corresponding to one of a fast scanning or a slow scanning direction of a scanning device for carrying out the printing, the $m \times 1$ pixel window starting at a pixel contiguous with the one or more pixels corresponding to the isolated hole, m being an integer;

20

comparing the second sum of turned off pixels in the $m \times 1$ pixel window to a second threshold sum; and turning off at least the first number of one or more pixels in the second pixel ring when the second number of turned off pixels is less than the second threshold SUM.

5. The method of claim **1** further comprising:

determining a third sum of pixels, corresponding to a number of holes different from the isolated hole, that are in a turned off state in at least a half scan line in one of a fast scanning and a slow scanning direction;

comparing the third sum of pixels to a third threshold number; and

turning off at least the first number of one or more pixels in at least the second pixel ring when the third sum of turned off pixels is less than the third threshold number for carrying out the outputting.

6. The method of claim **5**, wherein the third threshold sum is a weighted percentage of pixels in one of the fast scanning or the slow scanning directions that are in a turned off state with respect to a total number of pixels, the threshold sum being programmable.

7. The method of claim **1**, wherein the turning off at least the first number of pixels includes turning off at least two, at least three, or at least four pixels, of which at least one, at least two, at least three, and at least four pixels is contiguous with the one or more pixels corresponding to the isolated hole, such that the turned off first number of pixels become a part of the one or more pixels corresponding to the isolated hole during the outputting.

8. The method of claim **1** further comprising:

turning off a second number of pixels in the first pixel ring when the first sum of pixels in the on state is greater than the first threshold sum.

9. The method of claim **1**, wherein the one or more processors are further configured to:

turn off a second number of pixels in the first pixel ring when the first sum of pixels in the on state is greater than the first threshold sum.

10. A system for processing isolated holes of an image to be printed by a printer, the system comprising:

one or more processors configured to:

detect whether one or more pixels corresponding to an isolated hole in the image are in an off state, the off state defined by a lower binary logic level relative to a binary logic level corresponding to an on pixel;

determine a first sum of pixels that are in an on state in a first pixel ring surrounding the one or more pixels corresponding to the isolated hole when the one or more pixels in the isolated hole are detected to be in the off state;

compare the first sum of pixels in the first pixel ring that are in the on state with a first threshold sum;

turn off a first number of one or more pixels in at least a second pixel ring either comprising of or surrounding the one or more pixels corresponding to the isolated hole when the first sum of pixels in the on state is greater than the first threshold sum, wherein the second pixel ring is inside the first pixel ring; and

output the isolated hole including the turned off first number of pixels in the second pixel ring on a printable medium as an output image.

11. The system of claim **10**, wherein both the first and the second pixel ring comprise pixels in at least one of a fast scanning and a slow scanning direction of a scanning device, and wherein the first and the second pixel rings together define a two-dimensional neighborhood of the isolated hole

21

with one dimension corresponding to the fast scanning direction and another dimension corresponding to the slow scanning direction.

12. The system of claim 10, wherein the one or more processors are further configured to:

determine one or more pixel distances of one or more pixels in a turned off state nearest to the one or more pixels corresponding to the isolated hole;

compare each pixel distance to a threshold pixel distance; and

turn off the first number of one or more pixels based upon the comparison such that the turning off is carried out when one or more of the pixel distances are greater than the threshold pixel distance.

13. The system of claim 10 wherein the one or more processors are further configured to:

determine using an n-bit counter device a second sum of pixels that are in a turned off state in an $m \times 1$ pixel window corresponding to one of a fast scanning or a slow scanning direction of a scanning device for carrying out the printing, the $m \times 1$ pixel window starting at a pixel contiguous with the one or more pixels corresponding to the isolated hole, m being an integer;

compare the second sum of turned off pixels in the $m \times 1$ pixel window to a second threshold sum; and

turn off at least the first number of one or more pixels in the second pixel ring when the second sum of turned off pixels is less than the second threshold sum.

14. The system of claim 10, wherein the one or more processors are further configured to:

determine a third sum of pixels, corresponding to a number of holes different from the isolated hole, that are in a turned off state in at least a half scan line in one of a fast scanning and a slow scanning direction;

compare the third sum of pixels to a third threshold sum; and

turn off at least the first number of one or more pixels in at least the second pixel ring when the third sum of turned off pixels is less than the third threshold sum for outputting the isolated hole.

15. The system of claim 14, wherein the third threshold sum is a weighted percentage of pixels in one of the fast scanning or the slow scanning directions that are in an off state with respect to a total number of pixels, the threshold sum being programmable.

22

16. The system of claim 10, wherein the turned off at least the first number of pixels includes turning off at least two, at least three, or at least four pixels, at least one of which at least two, at least three, and at least four pixels is contiguous with the one or more pixels corresponding to the isolated hole, such that the turned off first number of pixels become a part of the one or more pixels corresponding to the isolated hole during the outputting.

17. A non-transitory computer-readable storage medium having one or more computer-readable instructions thereon for processing isolated holes of an image to be printed by a printer, which when executed by one or more processors cause the one or more processors to:

detect whether one or more pixels corresponding to an isolated hole in the image are in an off state, the off state defined by a lower binary logic level relative to a binary logic level corresponding to an on pixel;

determine a first sum of pixels that are in an on state in a first pixel ring surrounding the one or more pixels corresponding to the isolated hole when the one or more pixels in the isolated hole are detected to be in the off state;

compare the first sum of pixels in the first pixel ring that are in the on state with a first threshold sum;

turn off a first number of one or more pixels in at least a second pixel ring either comprising of or surrounding the one or more pixels corresponding to the isolated hole when the first sum of pixels in the on state is greater than the first threshold sum, wherein the second pixel ring is inside the first pixel ring;

turn off a second number of pixels in the first pixel ring when the first sum of pixels in the on state is greater than the first threshold sum; and

output the isolated hole including the turned off first number of pixels in the second pixel ring on a printable medium as an output image.

18. The medium of claim 17, wherein both the first and the second pixel ring comprise pixels in at least one of a fast scanning and a slow scanning direction of a scanning device, and wherein the first and the second pixel rings together define a two-dimensional neighborhood of the isolated hole with one dimension corresponding to the fast scanning direction and another dimension corresponding to the slow scanning direction.

* * * * *